TYNDALE (J. H.)

INFLUENCE OF ALTITUDES

—ON—

CONSUMPTIVES.

BY
J. HILGARD TYNDALE, M. D.,
NEW YORK.

[*Reprint from the St. Louis Courier of Medicine, March*, 1879.]

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By J. Hilgard Tyndale, New York.

THE curative influence of high altitudes in checking the progress of pulmonary consumption is beginning to be universally recognized by the medical profession.

In Germany, Dr. Brehmer, of Goerbersdorf, in Silesia, first started a sanitarium for the treatment of phthisical patients. On account of the active opposition of the Berlin professors, it was some four years before he succeeded in obtaining a concession from his government. But truth will prevail, even in medicine, in which deeply-rooted prejudices oft seem to gather strength as time advances.

Brehmer held that reduced atmospheric pressure, the constant sojourn of a phthisical patient in an atmosphere rarified and pure, was the proper food for the diseased lung, and, as such, was to be considered the long-sought-for agent for the cure of consumption. The idea that a reduction of about one-sixth to one-fifth of the pressure of the air column should be the means of bringing about such results as were actually accomplished by Brehmer's treatment, was ridiculed by these same authorities, and some vials of wrath, in the shape of publications, were poured out over his head. The undoubted success of his method is attributed to a change of habits and of surroundings of the invalid, aided by Dr. B's local treatment by shower-bath, etc. Later on

I will present my theory of what agents constitute the true remedy for the collective conditions known as phthisis pulmonalis, and based as it is upon the truths of natural philosophy, hope to have it acknowledged in the future that it is the true solution of the great problem of successful treatment of consumption. But I will not anticipate.

In Europe there are now three or four health resorts at high altitudes. In this country attention has been drawn to the subject by Drs. Loomis, Dennison and others, chiefly at the sessions of the American Medical Association. One sanitarium is in successful operation at Asheville, North Carolina, situated on a spur of the Blue Ridge Mountains. The elevation at that point is 2,250 feet above the level of the sea, and it is in connection with this elevation that I wish to offer a point for consideration.

It has been found that, in order to find almost perfect immunity from phthisis, an increased elevation is required as we approach the equator from the north or south, and this additional altitude is reckoned to be 300 feet for every degree of latitude towards the equator. Thus in Northern Germany, immunity from phthisis is placed at about 1,600 feet (Goerbersdorf is 1,715 feet); in Switzerland, from 4,500 to 5,000 feet; under the equator, at from 10,000 to 11,000 feet. If we examine the elevated regions of this country (I confine myself to the United States), we find that the mountain ranges of the East present no high upland plateaux of any great dimensions. Single mountain spurs and *strictly localized plateaux* are there, but even these latter have not the requisite altitude which their latitude calls for. It is so in North Carolina, where the Southern region calls for fully double the altitudes which exist, as at and near Asheville. It is the same in Western Tennessee, where, in addition to lack of elevation, the favored spots are so small, cramped, confined to a limited space, as to be accessible to and affected by all the noxious influences of the surrounding lower regions. As this subject will be again referred to, I will only add here

that in Colorado the immunity from phthisis is placed at 6,000 feet. And Colorado is in a more northern latitude than North Carolina and Tennessee.

The western part of North Carolina and the mountains of Eastern Tennessee serve to illustrate all that can be said for and against *medium altitudes*, though there are other sections of this country and South America, which come under the same heading. In their favor it is held that they are advantageous resorts for cases in which high altitude is not well borne, or not at all permissible. Such cases are rare. Further on I will show that patients who are not so far advanced in phthisis as to leave them no chance save to die at home and among friends, can safely be taken to an altitude where consumption is unknown. Now, it will be said, the altitudes at which approximate immunity from phthisis is found are very high altitudes, the sudden change to which might endanger the patient's life. Be it remembered that strictly localized high altitudes (single mountain tops, for instance) are not to be counted as health resorts, under any circumstances. High altitudes, however, of vast extent are approached by gradually rising ground, thus affording the invalid a chance to make a slow ascent without seeking a different part of the hemisphere each time a change becomes necessary.

The second objection to medium altitudes, as existing in this country as well as in Europe, is, as I have said, their limited extent, confining the invalid to a prescribed locality. I do not mean to say that such localities are cramped up within a narrow space, because I know better. What I do mean to say is, they are in no case extensive enough to be free from the influences of the surrounding lowlands.

Last, but not least, comes the objection that even such resorts as are high enough for their particular latitude (as the northern ones of Europe) are burdened with an excess of moisture, gathered by the mountains, exposed as they are to the moist Atlantic currents.

It will be seen, therefore, that the ideal resort for consumptives must have other attributes than elevation alone. One of these is *absolute inland position.* This would point to the Rocky Mountains as the most desirable range, running, if not through the geographical center of the country, at least sufficiently distant from the great oceans. Of the whole range again we should prefer the eastern slope of the Rocky Mountains, and, to keep within proper latitude, that portion which we find in Colorado, and including the northern half of New Mexico, and the northeast corner of Arizona. In addition, we count in as approaches the whole western half of Kansas. This gives us, as an *approach to the higher altitudes*, a vast plain, from the Missouri River to the foot of the Rocky Mountains, with a rise so gradual that it appears to be a perfect level, until at the foot-hills of the Rocky Mountains an altitude of 4,000 feet has been reached.

Then comes the mountain range itself, *interspersed with high plateaux* of various altitudes, from 5,000 feet to 12,000 feet, the whole extending over the entire State of Colorado and a goodly portion of the neighboring States. The highest of these mountain peaks range from 11,000 feet (Mt. Cameron) to 14,000 feet and some hundreds (Long's and Pike's Peak).

Again, we find among the foot-hills, *parks of lesser dimensions*, in many cases covered by pine forests. "Foot-hills" must not be confounded with hills in any other part of the country, since their average elevation is about 8,000 feet.

The same favorable general and local conditions exist in some parts of New Mexico and Arizona, but these sections are at present more or less inaccessible. Speaking of the continuation of the elevated plateaux in Mexico, Dr. Dennison says: "These exceedingly dry, elevated plains, including extensions to the north, into New Mexico and Arizona, would claim much more of our interest and study were the habits and lives of their greasy original inhabi-

tants more inviting and congenial to the cultivated American. The loose sand and fine lime-dust, together with the rapidly increasing growth of the prickly and inhospitable cactus, as you go south and southwest from Colorado, may reasonably indicate the undesirableness of much of that southern region."

Our duty in this generation, with regard to the treatment of phthisis, is, first, to arrive at definite conclusions as to what should constitute an *ideal* health resort for consumptives; and, secondly, to adapt this ideal to the standard of what we find of *real* localities among the varied climates of the earth, which answer all requirements, so far as scientific research may have determined them.

In selecting such a region we must assure ourselves of its possessing four qualifications, *sine qua non:*

1. It must be accessible to mankind; railroad facilities should be near.

2. The comforts of life should be as nearly the same as invalids are accustomed to at home.

3. The locality should have much and varied scenery as surroundings, and not be a limited oasis in a desert.

4. If a town or village, it should be one the future of which is more or less secured, and not open to the possibility of early decay.

As yet we have no established rules for the treatment of pulmonary phthisis, as regards the exact elevation, average temperature, humidity, amount of sunshine, electric tension, the suddenness, direction and velocity of winds.

Not even the experiences of the European sanitaria (Goerbersdorf, Davos, Falkenstein) are as yet out of their infancy. Most of them would not be applicable to this country, except as to generalities, least of all to Colorado, no such enormous inland plateaux of great elevation throughout, existing in Europe.

The various attributes of climate above mentioned are intimately interwoven, and dependent upon each other. These points will be enlarged upon when I come to speak

of and explain my new theory in regard to the climatic therapeutics of pulmonary phthisis.

Of *elevation*, the general rule holds good, that the nearer the equator the greater should be the elevation. It has been calculated that for every degree of latitude toward the equator, an additional elevation of 300 feet is requisite.

The *temperature* of high altitudes is, of course, lower than on the level ground at sea-level; that is, it is at all times cooler. Near the equator, this is very desirable. As with elevation, so it has been calculated with temperature, that its decrease is about 1° Fahrenheit for each 300 feet of elevation. This is not true in all cases, but holds good as a general rule. The mean annual temperature on the eastern slope of the Rocky Mountains, for instance, is higher than the average elevation would seem to indicate. Thus, the remarkable fact is developed, that the mean thermometrical showing (whether daily, monthly, or annual) of elevated stations at the base of the Rocky Mountains is *higher* than in the same latitude on the Atlantic coast, or the Pacific, and in the Mississippi Valley. The explanation of this is found in what I have dwelt upon before, to-wit: the *far inland position*. The rays of the sun pass through the rarefied air almost unobstructed. They fall upon land and water. The specific heat of water is four times as great as that of land, and when heat rays strike this land surface without having lost any of their power, they will be absorbed far more rapidly than by water. Now, the greater the surface presented, the more heat can be absorbed, and this condition is present in the shape of the upturned sides of the mountains presenting a greatly increased surface for the action of the sun's rays. But the earth which so readily absorbs heat, as readily gives it out at night-fall into a dry atmosphere, and, of course, causes as sudden and great a falling of the thermometer as it had at sunrise caused a rising. Thus, the ample daily and yearly fluctuations are caused.

Besides, the *mountains protect* the plateaux from strong winds and moisture which they gather, allowing the sun

shine to prevail on the level ground. The mountains protect the plateaux mostly to west and northwest. In high altitudes, the capacity of the rarefied air for holding moisture is very much reduced.

Then there is the *dry, sandy soil*, which rapidly absorbs moisture, being only slightly covered with buffalo grass.

Rivers and creeks, as sources of moisture, are scarce. So are trees, comparatively speaking, and what of moisture is gathered by them during a rain storm is afterwards rapidly absorbed by the dry atmosphere.

Humidity, *coolness*, and *dryness* of the atmosphere are increased by increased elevation. The expansion of air under the influence of solar heat increases its capacity for holding and retaining vapor. Now, the elastic force of vapor, or the absolute humidity of the air, diminishes with height, though as yet we do not know at what established rate, if any. Of the air becoming more and more rarefied by increased elevation, we know that it is twice rarefied at a height of three and one-half miles, four times at seven miles, sixteen times at fourteen miles, and so on in regular multiples of four. It is natural, and we are not surprised to learn from Prof. Tyndall that this expansion of the air, at such a rapidly increasing rate, with increasing elevation, is accompanied with a loss of a part of its humid contents.

I have shown that the earth has four times the capacity for absorbing heat as water, and how in high regions, surrounded by mountains, turned up as it were, and presenting their surface to the sun, the absorption of heat goes on very rapidly, and quickly warms the enclosed plateau. The *degrees of heat* are, of course, correspondingly *great*, and would so be felt at low altitudes, especially when laden with moisture; but on high plateaux of 6,000 feet, where, in the natural course of things, it ought to be cold, *the higher degrees serve to cancel the one degree of Fahrenheit of reduced temperature for each 300 feet of elevation, and thus what is thermometrically great will convey only the sensation of comfort.* Thus, at 6,000 feet, we would have: At 92° Fahr.

in the shade, the sensation conveyed the same as if it was 72°, minus any appreciable moisture, and plus all the beneficial effects of the intense sunlight. In winter, should the thermometer indicate zero, this would be felt as if it were 20° to 25° above zero, with the same addition of light and rapid warming of the earth's surface as soon as the sun rises, and its rays pass unobstructed through the rarefied atmosphere.

Or, to make my meaning still plainer: For each 300 feet of increased elevation the temperature is reduced about one degree of Fahrenheit. The heat of summer, therefore, (as indicated by the thermometer) would be the same at 6,000 feet as at sea-level, but for this reduction of one degree for 300 feet, which at 6,000 feet is equal to twenty degrees. In winter, the thing is reversed: On the one hand, a low temperature, as indicated by the thermometer, but not by our sensations. These are largely governed by the relative amount of moisture. So, we have, on the other hand, as an off-set to the thermometrical showing: Absence of moisture, almost continued unobstructed rays of heat and light, which have to penetrate no mist before reaching us, a more than double expanse of surface absorbing the heat (by the up-turned sides of mountains), and the protection against winds which these latter afford.

The *absolute humidity* in high altitudes is likewise less than in the lowlands; that is, this rarefied air, with three pounds of pressure to the square inch less than in the lower altitudes, has a diminished capacity for holding moisture. Thus, in Denver, (I quote from a statement by Dr. Dennison) the average cubic foot of air contained 1.13 grains of vapor at a mean temperature of 33°, while at Jacksonville, Florida, during the same time (five cold months), there were 3.92 grains of vapor to the cubic foot of air at a mean temperature of sixty degrees.

High altitudes, therefore, enjoy remarkable dryness throughout the year. And nowhere is this the case more than in Colorado, with its high and varying altitudes throughout the whole of the State. So great indeed is this

dryness, that the limited amount of rain-fall, including snow, which rain is, moreover, rapidly absorbed by the sandy soil, barely suffices to supply the necessary moisture for the scanty indigenous vegetation.

Again, I cannot too often recur to that greatest of features in the high altitudes of Colorado: The wonderful and uniform clearness of the air, as shown by the intensity of the sunlight. So clear is the air, and so intensely blue the sky, that, for the first few days of a stay in Colorado, you find it to your advantage to wear smoked glasses.

In regard to dryness of the atmosphere as one of the factors in the treatment of phthisis, the opinion expressed by Dr. C. T. Williams, of England, represents the accepted idea: "*It has been shown that, taking collectively all forms and degrees of phthisis, the dry climates are the most likely to arrest the disease.*"

Take, on the one hand, the effects destructive of life, such as we find them in mines, cellars, and ill-lighted abodes, and on the other, the benefits of sunlight at low levels, where a stratum of moisture intercepts the sun's rays like a thin cloud. Take away the moisture and the interception of the sunlight, and we have the unobstructed full effect of a sun-bath in the highlands, as found in Colorado. The sun's rays being less obstructed, two effects are produced:

First. Much more rapid taking up of warmth by the earth, presenting as it does, with the mountain sides, a largely increased expanse of surface,

Second. The sun shining unobstructedly in a *usually cloudless sky* (cloudless far in excess of other sections of the country), there is a proportionately *longer* influence of sunshine in each twenty-four hours; the sunlight, likewise, is more *intense* because steady, by being, as it were, undisturbed. Thus, we have, even on days during which the sun would be clearly visible for eight hours only, a sun-bath which in its *intensity*, *purity*, and *fullness of effect* makes up for the little deficiency in time, and may be said to have *fully double the effect on the human system than on the plains below.* It is for this reason that Dr. Dennison feels

justified in setting forth as a maxim that: "The beneficial effects of sunshine increase with increasing altitude."

Atmospheric Electricity.—We know more of electricity as a therapeutical agent than we do of the element itself. Among the established facts is, that electric tension in the atmosphere is increased with each decided elevation. Excepting during storms, when the atmospheric electricity is negative, we have it from extensive observations, that when the sky is clear the electricity of the air is always positive. Dr. Dennison says: "It would seem that with the increase of tension due to elevation, the positive electricity of the air, so abundant in dry elevated regions, would be constantly nearing the negative electricity of the earth." The high electric tension of high altitudes is no doubt due to this, though we have no other proof of this than our own nervous sensations. Houses, trees, and all other shelters for the human race only serve to intercept this vital fluid.

In outdoor life, there is no hindrance to its full action, and the human body is the receiving medium between the positive electricity of the air and the negative electricity of the earth. This fact, too, is a plea in favor of sleeping on the ground in open air, because "you *get up in the morning from your negative electric bed to stretch yourself in the positive electric air.*"

Of *ozone* as a curative power, nothing is known, and its utility is a matter of speculation. What is known is, that in Colorado as well as at other great altitudes, the increase of ozone in the mountains is shown, as compared with the plains below.

Winds.—As a general thing, a moderate amount of wind has a decidedly healthful influence in keeping the air in motion. A rapidly moving, chilling wind, alone can be of harm to the human organism, by the too rapid reduction of the temperature of the external surface of our bodies. In such high regions as the Rocky Mountains, the general movement of the air is, of course, greater than in the lowlands, but the difference is not so great as one

would suppose, excepting on high, exposed plateaux, chiefly the so-called divides, where the force of the wind has it all its own way. The topography of the country, on the other hand, the variety of shapes and relative position of mountain ranges to each other, naturally brings about a great variety of strictly local conditions. The predominating features are the more or less limited high plateaux, for the greater part (two-thirds to three-fourths) surrounded by mountains, which break the force of the winds. Luckily too, this protection is chiefly in the north and northeast, from which directions the most disagreeable winds are to be expected. For, as a rule, it may be set down for the eastern slope of the Rocky Mountains in Colorado, that the south, southwest and west winds bring pleasant weather, while their opposites, the north, northeast and east winds bring most of the rain.

Again, it should be borne in mind that the winds in these high altitudes, though moving with the same rapidity as on the plains, *exercise much less force on account of the reduced weight of the atmosphere, due to elevation.* So, while purifying the air and changing it, the force of the wind does not suffice to create discomfort by rapid cooling off of the outer man, nor exercises any chilling effects upon the respiratory mucous membranes of the inner man.

The general effects of *altitude* on man are well understood, when we consider the lessened pressure of the air-column, which exists at great elevations. The surface of a man's body may be said to be sixteen square feet, and the pressure of the air-column upon a square centimeter of surface at mean barometric pressure 1033 grammes.

At the height of 6,000 feet (the average height of the foot-hill plateaux of Colorado), the surface of the human body is relieved of a pressure of three pounds to the square inch, which is equal to 7,000 pounds for the whole man. So much for the outer surface. The respiratory mucous membrane of the lung has been calculated by Lieberkuehn to be 1,400 square feet. The lungs are the organs chiefly influenced by the reduced pressure of the air-column,

whereby primarily *increased activity in breathing* is brought about, which in turn secondarily influences the centres of circulation, assimilation, and innervation. In a comparatively short space of time, these functions will have accommodated themselves to the change. The proportions of oxygen, nitrogen, and carbonic acid are the same at high altitudes as at sea-level. At the height of 6,000 feet, where the pressure of the air-column is diminished one-fifth, a given space of air will, of course, contain one-fifth less of oxygen, and, therefore, at first the lungs must inspire a fifth more of air to get the same amount of oxygen.

The oft-disputed question, whether *increased frequency of respiratory movements, or greater profoundness in breathing* makes up this one-fifth deficiency, is best decided by first examining the known effects of inspiring rarefied air, and expiring into it, at low altitudes. These effects can be summed up as follows: First. The muscles of inspiration are strengthened, inasmuch as the atmospheric pressure in the lungs is lessened, while that on the surface of the chest remains the same; second, there is a greater determination of blood to the lungs from relaxation of the tension on the ubes and air-vesicles. This relaxation allows the lung to contract in the exhaling process, and by expulsion diminish the amount of residual air. Let it now, for a moment, be kept in mind, that this *increases the capacity for taking in of air;* third, the blood being determined to the lungs, the left heart is relieved somewhat from pressure, and this causes, as we know, at first, rapid action and softness; fourth, elimination of carbonic acid is favored, because of the diminished density of the inspired air. So we have of *immediate* effects: Increase of venous blood in the lungs, rapid action of heart, increased riddance of carbonic acid, and increased room in the air-vesicles for fresh air. Now let us first, and entirely overlooking the permanent effects for the present, transfer these facts to our high elevation, where we also inspire and expire into rarefied air, but with the difference from the foregoing, that now the pressure on the outside of the chest is *diminished* (for convenience

sake we will say one-fifth). Then we will get of immediate effects mentioned above, only those which are caused by a rather sudden change from a denser to a rarer medium. And these effects are always temporary unbalancings of the functions, are *disturbances of innervation*, pure and simple, manifested by rapid breathing and accelerated heart's action. Increased rapidity of propulsion causes not merely fullness of bloodvessels in the lung, but *drives the blood into and through the capillaries;* it begets a *determination to the periphery*, as any one can notice upon himself before he has been in Colorado many hours. Let us say then, that lungs and periphery (lesser and greater circulation both) are in a *temporary state of venous fullness*, caused by a disturbance of innervation of lungs and heart from an unaccustomed change from dense to rare medium. The lungs will rid themselves first of this stasis by taking in oxygen. But the peripheral stasis can only be permanently relieved after the left heart has acquired more force of contractility by oxygenated blood, and the right heart is no longer crowded by backward pressure from the lung. Of course, I am fully aware that such conditions cannot exist for any great length of time, and I have taken care to speak of them as "temporary." Yet, both the capacity of the system for standing changes of any kind for a length of time, as well as that the compensating hypertrophies (heart), and dilatations (air receptacles, and subsequently chest-walls), take place in a comparatively short space of time, are facts too often overlooked. *The stasis is soon compensated for, and answered by* dilatation of the capillaries, and their consequent increased capacity for holding blood. In inspiration of rarefied air at sea-level, carried on through a number of months, daily, the effects outline the respiratory act, and in a measure beget hypertrophy of the heart's muscle, and a moderate expansion of air-vesicles, through increase of their contractility. Eventually, however, the outside pressure of the air-column will regain its supremacy sufficiently to cancel most of the benefit derived. Not so in the rarefied air of high altitudes, where

the pressure of the air-column is at all times reduced, barely disturbed by any rise of the barometer, because moisture is wanting. Here the permanent conditions will bring about permanent changes, to-wit: Hypertrophy of the muscular tissue of the heart, and distension of the pulmonary respiratory membrane as represented by the air-vesicles.

Now, let us not forget that the endosmotic action of oxygen through the lung-membrane is of a *more rapid and thorough kind* in the clear, rarefied air, the very rarefaction of which is a guaranty for its ready passage through membranes. The increased elimination of carbonic acid, at first due to determination of a larger quantity of blood, and answered by increased absorption of oxygen through more rapid inspirations, is now answered by deeper and fuller inspirations, and the taking up of the same quantity of oxygen as before. As soon, then, as increased frequency of respiration and heart's action approach the normal once more, to be supplanted by deep, full respirations and regular but more powerful heart's action, we are justified in believing that the *respiratory function has adapted itself to the change of elevation.* Dilatation of the capillaries and expansion and tension of the air-vesicles with their sub-structure of elastic tissue have now become permanent, as evidenced by enlargement of the circumference of the chest.

To recapitulate: THE LESSENED PRESSURE OF THE ATMOSPHERIC COLUMN FROM WITHOUT IS ANSWERED BY INCREASED ACTIVITY OF THE ORGANS WITHIN, WHICH RESULTS IN HYPERTROPHY OF THE MUSCLES OF THE HEART, FULLNESS AND SUBSEQUENT DILATATION OF THE PULMONARY AND PERIPHERAL CAPILLARIES AND EXPANSION OF THE AIR-CELLS. THESE CHANGES BEGET PERFECT ADAPTATION TO THE CHANGE OF ELEVATION, AND RE-ESTABLISH THE EQUILIBRIUM PREVIOUSLY EXISTING BETWEEN EXTERNAL AND INTERNAL FORCES.

This explanation readily accounts for the varied effects upon the circulation of different persons, and chiefly as

regards cases of hæmorrhage from the lungs. Every individual, whether safe and sound or afflicted with disease, has to pass through—first, the *functional* changes, and second, the resulting *organic* changes. The character of the tissues of the heart and blood-vessels will determine the issue in each case. For the great majority, even of sick persons, great reliance may safely be placed upon the wonderful adaptability of the human organism to all manner of changes. But a heart loaded down with fat, blood-vessels whose elasticity has been impaired by atheromatous changes, calcareous deposits, or when resistance to the pressure of blood is diminished by syphilitic or scorbutic changes, or the hæmorrhagic diathesis (more frequent than is generally allowed); stumps of occluded vessels, from whose mouths hæmorrhage has occurred before—all such may give way under the increased pressure, and a hæmorrhage be the result. This speaks for the safety of the plan of slowly and gradually crawling up toward high elevations. At the same time a slight hæmorrhage need not necessarily be fatal, and will in all human probability not occur again. The time spent and lost in reaching the proper altitude by very slow stages, may prove fatal. Where no hæmorrhage has taken place in some months, the danger of a sudden change cannot be so great.

As before stated, the altitude of approximate immunity from phthisis is required to be higher the nearer we move towards the equator, and it has been asserted by Brehmer to be equal to 300 feet of rise to every degree of latitude. Such a calculation would not amount to much in itself, were it not in consonance with the total absence of phthisis among the inhabitants of these increased altitudes. The altitude of immunity in Colorado, has been found, by the necessarily limited observations thus far at hand, to be 6,000 feet. A great portion of Southern Colorado and its high plateaux on the eastern slope of the Rocky Mountains have an average altitude of 6,000 feet and somewhat above. According to surveys by Professors Parry, Hayden and others, the following altitudes are correct:

Average elevation of foot-hills, about 8,000 feet. Summit of the range, 11,500 feet. Timber line, from 11,800 to 12,000 feet.

For convenience sake, I divide the plateaux and localities under three heads:

First. Among the foot-hills, and ranging from 4,000 to 7,000 feet. Of such are Boulder (5,536 ft.), Canon City (4,700 ft.), Colorado Springs (5,975 ft.), Denver (5,317 ft.), Manitou (6,124 ft.), Pueblo (4,400 ft.), San Luis Valley (6,400 ft.).

Second. Higher plateaux among the mountains of average height and below timber line, from 7,000 to 11,000 feet. Here we have Manitou Park (7,752 ft.), Middle Park, head, (8,690 ft.); Estes' Park (7,528 ft.), Morrison (9,842 ft.), Hot Springs (7,725 ft.), Georgetown (8,466 ft.), Montezuma (10,113 ft.).

Third. The elevated prairies of Western Kansas and Eastern Colorado, which might be designated as approaches to the Rocky Mountains, and with a continual rise from 2,000 to 5,000 feet. Among these I will mention Lachine, Kansas; Kit Carson, Colorado, (4,191 ft.).

The elevations above timber-line consist of the solitary peaks of great altitude, such as Pike's Peak (14,436 ft.), Mt. Lincoln (14,183 ft.), Mt. Wright (11,800 ft.), Long's Peak (14,300 ft.). These altitudes are not for consumptives.

Let me now summarize the general facts in regard to high altitudes and their utility. Part of the conclusions are derived from Dr. Denison's instructive monogram.

1. Cool and dry are better than warm and moist climates.

2. The only favorable attributes of low altitudes, dryness of the air and diathermancy, are found multiplied in high altitudes.

3. The uniformly warm climate of southern regions, (Florida, Bermuda Islands etc.), with their high thermometrical reading without noticeable falls, is at last beginning to be recognized as relaxing, depressing and enervating factors, for which its equableness is no compensation.

4. The moist, salt air of sea-coasts is beneficial to the consumptive only in its purity and absence of malaria, but decidedly harmful in the too frequent absence of continued sunshine, and that greatest of factors necessary for consumptives, *uniform withdrawal of the watery constituents of the body* at large and the lungs in particular.

5. Almost any change of locality and climate, differing from the home climate, is of *temporary benefit* to consumptives, as well as to other folk. But consumptives have no time to fool away. It is this temporary benefit upon which is founded that monstrous assertion that miasmatic sections had been found to be a paradise for consumptives, and *vice versa*.

6. The benefits of high altitudes are not contained in the one factor of low barometric pressure, as still adhered to by Brehmer. The three chief factors are doubtless the three imponderable agents, *heat*, *light* and *electricity*, with their separate and combined influences on the human organism, consisting, broadly stated, of rapid change of tissue and strengthening of functions, with consequent strengthening of organs by gradual accommodation and adaptation.

7. The detailed requisites of high altitudes, in order to derive benefit therefrom, consist of

(*a*) Rarified air. Pressure of the air-column must be reduced from one-sixth to one-fifth.

(*b*) Heat-rays of the sun coming unobstructed through rarefied atmosphere, quickly warming the earth's crust.

(*c*) Rays of light should be equally unobstructed, giving a steady and intense light, a uniform sun-bath.

(*d*) High mountains, enclosing upland plateaux from two-thirds to three-fourths of the circumference, sheltering them from strong winds, and adding vastly to the expanse of earth warmed by the sun.

(*e*) Increased electric tension. The undoubted benefit derived from the positive electricity of the air, and the negative electricity of the earth, with the patient as a medium.

(*f*) The presence, within reasonable reach, of pine forests, for the benefits derived from inhaling their odors. Also, other plateaux, to the north and south of the chosen one, for changes in summer and winter. The most preferable would be one of somewhat increased altitude to the north and of lesser to the south.

(*g*) Moisture, just sufficient to keep the land from becoming a desert; in other words, a limited rain-fall throughout the year.

All of these requirements and their attendant benefits are to be found along the eastern slope of the Rocky Mountains, extending through Colorado and parts of New Mexico and Arizona. The same conditions on the same gigantic scale are nowhere else to be found.

Coming to look at the seeming disadvantages, as they would appear to laymen, and as sometimes complained of by patients during the first weeks of their soj urn in Colorado, we find the following:

Frequent rains. This frequency is deceptive. It may rain on three successive days for one hour each day, which occasionally occurs as a sequel to three weeks or more of uninterrupted sunshine. The quantity of actual rain-fall by inches is barely sufficient to sustain vegetable and animal life, and is so rapidly absorbed by the sandy soil and taken up by the dry air, that often after a severe shower, no trace of moisture is left on the ground or upon the leaves of undergrowth in a couple of hours.

Occasional short-lived winds. The motion of the air is at all times barely sufficient to aid in purifying the air and changing it.

Let it be remembered here, that sudden changes, which do not occur often, nor create persistent change, are of decided benefit for all classes of chronic diseases. *Constant* dryness is anything but a desirable factor.

The cold weather is not felt as such, a fact previously dwelt upon. On account of the absence of moisture, the lowness of the temperature exerts only its tonic influence. It is in the winter, therefore, that most *cases of*

consumption reap the greatest benefit, the air being then extremely dry and highly electric, with no rain and very little snow. The thermometer shows great variations between day and night, sometimes going below zero; but, as before stated, the absence of any appreciable amount of moisture and the shelter of the hills, prevent any depressing influence from the low temperature being felt. With a moderate quantity of woolen clothing, only the bracing, tonic effects upon the human body are experienced. During the day, from 10 till 4, *the sun shines almost uninterruptedly*, and with such power as to enable the invalid to enjoy out-door exercise without additional wrap or overcoat.

The hill-sides do not, as has been too frequently asserted by medical men, also, act as a screen to the sun's rays, but *as a trap, concentrating their effect.*

I have no doubt that future experience will show the necessity of dividing the therapeutical directions under three general heads, as regards the primary disposal of patients:

1. Those in whom infiltrations not yet exulcerated, catarrhal processes consequent upon the foregoing and atelectatic lungs supervene, where the trouble is chronic and without very active tendencies. Includes chronic interstitial pneumonia. Such patients may likely have to reside in Colorado the greater part of the year, and yet be able to be at home the rest of the time. They can probably go to the elevation of 6,000 feet at once.

2. Those in whom destructive processes have begun, *limited, rather well-defined cavities* have formed, including bronchiectatic conditions and cheesy infiltrations; such in whom the sub-acute processes are still manifested by fever, but have not yet reached the colliquative stage, yet in whom there exists a constant tendency to conditions which disturb the balance of health, might begin with 4,000 feet, and in accordance with their more or less rapid improvement change to 5,000 or 6,000 feet.

3. Those in whom destructive processes are decidedly active; who have reached the colliquative stage;

where the destructive tendency has recently been manifested by *hæmoptysis;* finally, those afflicted with *acute miliary tuberculosis* (though now considered hopeless cases) might travel by slow stages through the gradual rise in Kansas, and remain a month or two at choice localities, such as Lachine, Kansas; next, go to Denver or Greeley, and from thence to Manitou.

The first two or three months of rational treatment would readily determine which of the second and third class would have to make Colorado their permanent home.

On a previous page, I have intimated my belief, that the three imponderable agents, HEAT, LIGHT, AND ELECTRICITY, IN THEIR COMBINED ACTION, SERVE TO STAY THE DISINTEGRATING CHANGES OF TISSUE IN THE HUMAN ORGANISM, AND THUS PAVE THE WAY TO THE CURE OF CONSUMPTION.

I now re-assert this as a theory upon which the therapeutics of phthisis will, in my opinion, be based in the future. The high elevations, and the rarefied atmosphere previously referred to, are free from all baneful influences in the three forms in which matter presents itself, namely: *solids, fluids, and gases.*

They are free from: *Dust* (as a solid), excessive *moisture* (as a fluid), and from *intoxicating vapors* (representing the gaseous form).

In the relatively total absence of these baneful influences at high elevations, the life-giving and life-sustaining agencies of heat, light, and electricity can and do have full and uninterrupted sway. We see, therefore, that it is on high, upland plateaux, far removed from large bodies of water alone, that these agents can exercise their powerful curative influence upon the human system to its fullest extent. In what way, I have pointed out. In how far these forces operate, by being converted into each other, is a matter for future investigation and speculation.

Now, if I insist once more upon the correctness of my theory concerning the cure of phthisis, it is because I am thoroughly convinced that it will prove to be the solution of the great problem of the proper therapeutics for all

forms of consumption. When once the use of the imponderable agents has been reduced to something like a system, by careful observation of their effects upon different forms and stages of phthisis pulmonalis, I am confident that this theory will be found to cover the whole ground. By careful individualization, and strict attention to detail in the therapeutical application of heat, light, and electricity, every form of consumption will finally be treated successfully on a scientific basis.

So important does it appear to me to have my theory well understood, that, at the risk of its being voted as tedious, the whole matter is here condensed once more, and the points presented in proper succession:

1. The products of phthisis are either *hereditarily scrofulous* or *directly inflammatory*, and are respectively known as: *hyperplasia of connective tissue*, *cheesy degeneration*, *and tubercle.*

2. When found in the lungs, we look upon them (generally speaking), as products of lessened and retarded nutritive changes in the lungs, caused by an *insufficient supply of blood* and its *consequent stagnation* from lack of central propulsion. These conditions may aptly be termed, "*increased venosity.*" Now, the vitality of a part being lowered by the amount of venous blood in it being out of natural proportion to the arterial, the nerves do not act sufficiently upon stimulation. For this reason, we find mucous membranes, which, in a state of proper vitality, secrete their special fluid in due proportion to the stimulus applied, and shed and renew their surface in exact proportion to the nervous influence they receive, acting irregularly in this respect. They now show little and imperfect re-action after the nerve-influence, which is natural to them, remaining sluggish and secreting an excess of fluid, and when more than ordinarily irritated are found to shed their coat unduly.

3. The accepted great therapeutical measure for the removal of these products by expectoration and absorption is the removal of patients to high elevations, where

the pressure of the air-column is reduced from one-sixth to one-fifth.

4. The curative influences of high elevations have been attributed by Brehmer to this lessened barometric pressure alone; in other words, to the effects of rarefied air. This has been ridiculed by other writers, but not successfully contradicted in the absence of other explanations.

With these facts in view, my deductions from them are as follows:

1. The healthy lungs, to properly perform their function, must have *pure, unadulterated air*. The infiltrated lung requires rarefied air, because by reduction of outside pressure alone, can the propulsive power of the heart be increased, and thereby overcome stagnation.

2. We next ask ourselves, why is this atmosphere unadulterated? Because of the proper action of *heat*, *light* and *electricity*, which agents manifest uninterrupted power through an almost purely unobstructed medium. It is unadulterated by dust, excessive moisture, noxious gases; representing in turn the three forms of matter: solids, liquids and gases.

3. The three imponderable agents have full play. Heat manifests all its beneficial effects upon the human system by that most important of regulating factors, withdrawal of water from the tissues of the body. Heat at high elevations is not restrained from diffusing itself by its various ways of transmission, radiation and convection. The rays of light pass unobstructedly through an ether of intensest blue, and consequently beget the nearest approach to white light at the proper elevation. Its distribution by radiation, refraction, etc., is untramelled. The effects of electricity at high altitudes manifest themselves in increase of ozone for breathing purposes, and in the positive electricity of the air, with its effects upon the human body as a medium between it and the negative electricity of the earth.

4. In addition, I hold that an upland plateau for therapeutical purposes must have three qualifications in order

to escape dust, moisture and gases: *Elevation* sufficient to exclude all dust not of its own local origin; *mountainous surroundings*, sufficient to break the force of winds and the noxial carried by them; *inland position*, removed as far as possible from the seas or any great body of water. Upon this latter point I lay particular stress, and insist, that any elevations still reached by moist sea-currents are not ideal health-resorts for consumptives. Thus any of the high altitudes west of the divides in the Rocky Mountains, as well as those of the Alleghany Mountains, are, though far removed from, still too near to either ocean or the Gulf of Mexico.

Both *sea and mountain air* are known to encourage and promote rapid change of substance, although they differ in the *modus operandi*. Both are subject to irregular variations of the barometer, as they are known to occur rapidly, and of short duration, both at the sea-side and in the mountains.

In contradistinction to wide plains, where slow changes of the barometer indicate equally slow and long-lasting rains, the sea-shore and the mountains have rapid changes, with rain of very short duration. These changes, once considered as productive of evil, are now known to be essential to the highest condition of health.

There is no doubt that *rapid changes of short duration are more favorable for the more important functions of the human body than relative stability.* We cannot endure either constant dryness or dampness, and since, therefore, barometric changes are necessary, such changes as take place rapidly, and having supplied the absolutely necessary amount of moisture only, equally as rapidly return to the normal and usual standard, must be of benefit to invalids.

These conditions are shared by sea-shore and mountains, as above stated.

The difference in action between sea and mountain air is now to be considered, of which Dr. Brown says, in substance:

Sea air acts rapidly, mountain air slowly; sea air very

soon compels a more increased ingestion of food, stimulates digestion powerfully, so that the bodily weight is considerably increased in a short time. Mountain air, on the other hand, acts as a more subtle, slow stimulant, exerts its influence beneficially on enfeebled bodily functions, and their naturally increased irritability. Sea air pre-supposes robust assimilative functions and equally robust integrity of the functions of the heart and lungs, however anæmic or otherwise enfeebled a person may be, if only their *circulation and nervous system are sufficiently above par to bear the strong stimulant.* Mountain air exercises a calming and indirect, quite gentle influence on the atonic and catarrhal conditions of mucous membranes, and, however persons may suffer from weakness with increased irritability, it will act slowly but surely beneficially, if only the circulation and nervous system are still *capable of responding to the gentle and scarcely perceptible influence of mountain air.*

I have stated my conviction (in which I am confident future statistics will bear me out) that dryness of the atmosphere, to be of lasting benefit to consumptives, must be as nearly absolute as possible, relieved by moisture only to the extent of keeping up limited vegetation. And such moisture must not be lingering, as, for instance, in the shape of dew. The average distance of localities in Colorado from the Gulf of Mexico is 800 miles, while the Atlantic and Pacific oceans, respectively, are more than 1,000 miles away.

Now there is, therefore, extraordinary dryness of atmosphere, which is only temporarily relieved during the summer months by occasional short-lived thunder storms. Nature supplies most excellent drainage, and water falling upon level ground is rapidly absorbed by the gravelly soil. In his pamphlet on the advantages of Manitou, in Southern Colorado, Dr. Solly says: "The buffalo grass forming a thick, dense sod, rapidly sheds the rain-fall, the surface water being carried away by the gulches and water courses, thus leaving an inappreciable amount of moisture to be taken up by the atmosphere. It is unquestionably owing

to the proximity of this enormous volume of dry air that *none of the evidences of damp are encountered at Manitou*, even in those occasional seasons, when the rain-fall is considerable.

Glancing once more at what at the present day we would consider our ideal of an elevated health-resort for phthisical patients, there is not one requirement that is not satisfactorily found in Colorado, and at some of its choice spots, such as Manitou, in particular. Let me rehearse these requirements and their fulfillment once more. In establishing certain facts it is utterly impossible to avoid repetition, and I condense as much as practicable.

1. High upland plateau, covering a considerable expanse of territory, the approach to which shall be a gradual rise, and with altitudes likewise extensive, which answer to the elevation required for immunity from phthisis in that latitude.

2. This plateau must be sufficiently far removed from the high seas or lakes of any size, in order to be entirely free from moist currents.

3. Occasional passing thunder storms of short duration are sufficient sources of moisture.

4. The plateau must not be above timber-line, or close to the snow-line. The presence of pine forests is a desirable object.

5. It must be sheltered from two-thirds to three-fourths of its circumference by mountains sufficiently high to protect the plateau from strong winds, but not high enough to render it shady. No straight pass or canyon should be situated at the entrance to the plateau, nor should it be traversed by a very frequented highway, where dust abounds.

6. The natural drainage of the plateau should be perfect, the soil sandy, firm, mixed with gravel.

7. A natural water-course of melted snow from the mountains in rapid motion and with rocky bottom.

8. Total absence of noxious vapors. Proximity to a large town should be avoided, and the plateau itself should

be so constituted as to preclude the possibility of a town of any size growing upon it.

9. A commercial centre of sufficient dignity, to serve as a base of supplies, to be within reasonable distance.

10. Other plateaux, or upland parks, within reachable distance, both north and south, to serve as a change for invalids in summer and winter. Also, variegated scenery in the more immediate neighborhood.

11. The plateau should be sufficiently open to admit of the greatest benefit being derived by the heat and light rays of the sun, so as to enable the invalid to have a sun-bath for not less than nine hours in the summer, and seven in the winter.

12. According to observations of several years past, one of the requisites is that the number of clear days shall approximate three-fourths of the 365 days in the year.

13. The variations of temperature should not exceed twenty degrees during any one of the four seasons of the year.

14. An average barometric pressure of twenty-four.

15. Presence of an increased quantiy of ozone in the atmosphere, engendered and replenished by the thunder-storms of short duration.

All of the general requirements enumerated, are found in Colorado, and the local ones in a number of localities in the northern, middle, and southern natural divisions of the State (north, middle, south, San Luis Parks).

A short rehearsal of the *disadvantages*, as they appear to the uninitiated, and form the basis of more or less frequent complaints, will not be out of place here:

First. The sudden changes, short as they usually are, are a prime necessity, constant dryness not being desirable.

Second. Cold weather, *at any season* (I refer to the sensations of invalids), is only bracing, and moisture, which some persons claim to be sensible of in various parts of Colorado, is absent.

Third. High degrees are not felt as such (90° Fahr. and upwards), moisture being rapidly withdrawn from the

body. This deficiency needs replenishing, and insures constant and rapid nutritive changes.

Fourth. Openness of a plateau to the northeast, towards the plains, brings no harmful winds, but plenty of pure, unadulterated, rarefied air from the high plains.

The only objections which hold good are the spring and autumn equinoctical changes, which, however, are of short duration. These occur all over the globe, of course. At such periods patients could make the changes previously mentioned to northern and southern localities, or else remain where they are, as their condition at such time would seem to indicate.